·油气采收率·

新型防水锁处理剂的研制与应用

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摘要:针对双河油田维护作业后水锁引起油井大幅减产的问题,通过室内实验研制出一种新型防水锁处理剂,其由质量分数为0.5%的SATRO、质量分数为0.05%的烷基磺酸钠和质量分数为0.03%的FX-02组成,并对该防水锁处理剂进行了配方筛选以及性能评价。结果表明,该新型防水锁处理剂能够有效降低油水间界面张力,使得油水界面张力达到超低(10^{-3} mN/m),同时具有良好的破乳性能,3 h内破乳率达90%以上。室内岩心物理模拟实验结果表明,当防水锁处理剂注入量为10倍孔隙体积,温度为70 ℃,驱替压力为0.3 MPa,反应时间达到8 h时,岩心渗透率保留率达85%以上,能够有效预防乳化堵塞和水锁效应对地层渗透率的伤害。现场已推广应用该防水锁处理剂12井次,有效率为100%。

关键词:水锁效应 防水锁处理剂 界面张力 破乳 双河油田
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油田进入开发后期地层压力下降,在维护作业中,采用清水冲砂、洗井,常因地层压力过低而造成大量清水漏入地层,甚至“倒灌”,从而引起乳化堵塞、水锁效应、粘土膨胀和颗粒运移等伤害,致使油井产油量下降甚至不产油。双河油田现处于高含水开发期,产量递减加快,在经历了维护作业后,减产尤为突出。前人进行的水锁伤害研究[1-5],主要集中在理论研究和室内评价方面,对预防水锁伤害的方法研究较少。笔者通过对水锁伤害机理的研究,在大量室内实验的基础上研制了一种新型防水锁处理剂,能够有效预防水锁伤害,现场应用效果显著。

1 配方筛选及评价

1.1 实验仪器及药品

实验仪器包括TX500C系列旋转界面张力测定仪、752型分光光度计、AE200型电子天平、BILON数显恒温水浴锅、HENC高速变频搅拌仪、具塞量筒和滴液漏斗。

实验药品包括表面活性剂SATRO,工业品;烷基磺酸钠,工业品;十二烷基苯磺酸钠,分析纯;破乳剂JPCI-1,FX-02,JL-10,JL-7,7421和TA1031,工业品;实验用水为江河联合站过滤液;实验用油为双河油田江8-13井地层原油;石油醚,分析纯。

1.2 表面活性剂复配体系优化

在TX500C系列旋转界面张力测定仪转速为5 800 r/min,测试温度为70 ℃的条件下,在实验室对不同质量分数的SATRO和烷基磺酸钠进行复配,分别对复配体系进行界面张力测定[6],界面张力均为对样品测试2 h后的稳定值。

通过一系列筛选实验,得出的最优复配体系由质量分数为0.5%的SATRO和质量分数为0.05%的烷基磺酸钠组成。该复配体系的动态界面张力(图1)随着时间的增加而下降,测定到60 min时达到最低值,为4.706×10^{-3} mN/m,之后基本达到稳定,体系达到动态平衡。

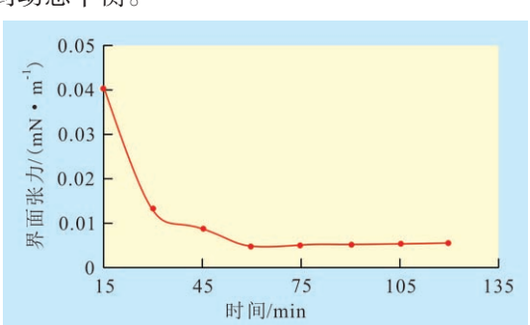

图1 表面活性剂复配体系界面张力与时间的关系

1.3 防乳化体系筛选

为防止外来水相流体与地层原油产生乳化堵

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塞，可在防水锁处理剂配方体系中加入破乳剂，使其具有破乳及防乳化的性能。在实验室对破乳剂进行破乳除油实验[7]，由于所配乳液的稳定性能欠佳，实验所使用的模拟O/W型乳状液需要在实验前1 h内配制。破乳剂的添加量为100 mg/L，破乳温度为70 ℃，破乳时间为120 min。根据评价实验结果（表1），FX-02的破乳性能较好。

表1　破乳剂对模拟原油乳状液的破乳结果

破乳剂	实验现象	溶液外观
7421	无油滴上浮	褐色
TA1031	无油滴上浮	褐色
JPCI-1	反应较慢，少量油滴上浮	浑浊
FX-02	反应迅速，大量油滴上浮	清澈
JL-10	反应较慢，少量油滴上浮	浑浊
JL-7	反应较慢，少量油滴上浮	浑浊

1.4　防水锁处理剂的性能评价

界面活性　通过对表面活性剂体系和防乳化体系的复配优化实验，最终筛选出防水锁处理剂的配方由质量分数为0.5%的SATRO、质量分数为0.05%的烷基磺酸钠和质量分数为0.03%的FX-02组成。为了进一步确定防水锁处理剂的界面活性，对体系进行动态界面张力测定。由图2可见，测定到60 min时，界面张力达到超低（10^{-3} mN/m），之后界面张力变化不大，体系达到动态平衡。

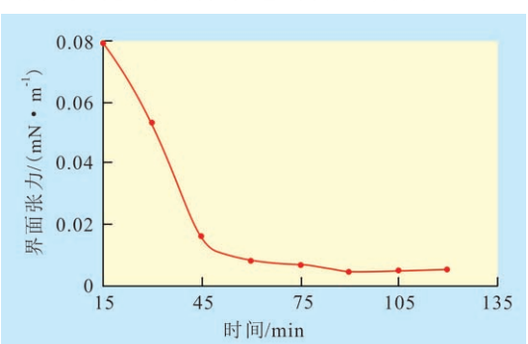

图2　防水锁处理剂界面张力随时间的变化

破乳性能　采用SY/T 0530—1993油田污水中含油量测定方法[8]进行破乳率的测定。考察了破乳温度为70 ℃，在不同破乳时间下防水锁处理剂对模拟含油乳状液的破乳效果。由图3可见，当破乳时间为0.5 h时，破乳率为49.8%；随着时间的增加，破乳率迅速上升，1.5 h时达到82.3%，之后增大，趋势变缓；当破乳时间达到3 h时破乳率达到90.4%，证明该防水锁处理剂具有良好的破乳性能。

物理性能指标　该防水锁处理剂为半透明液体，分散性良好，密度为0.92 g/cm³，pH值为6～7，与原油间的界面张力可达到超低，与地层水配伍性良好，耐温性能好。

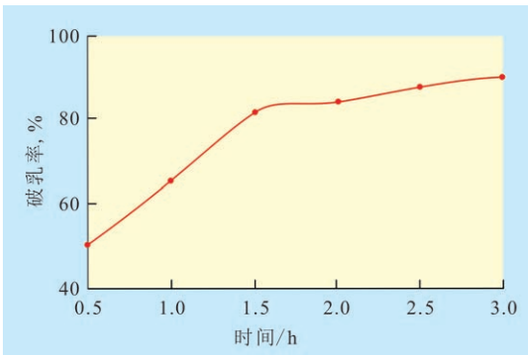

图3　防水锁处理剂破乳率随时间的变化

2　物理模拟实验

实验用岩心为双河油田砂岩岩心，其空气渗透率小于100×10^{-3} μm²，直径为2.5 cm，实验用地层水为江河联合站过滤液，实验用油为煤油稀释过的江8-13井地层原油（体积比为1.5∶1），为了防止驱替介质中固相颗粒造成伤害，均用孔隙直径为0.22 μm微孔滤膜过滤2次[9]。

2.1　水锁伤害实验

将岩心样品抽空，饱和地层水后，装入岩心夹持器中，在实验温度为70 ℃，驱替压力为0.3 MPa的条件下，用原油驱替，稳定后测得的油相渗透率作为初始渗透率；再将一定量的地层水反向通入岩心，模拟外来流体侵入过程，静置2 h后用原油驱替，稳定后测油相渗透率[10]。岩心水锁伤害结果（表2）表明，在油相渗透率稳定之后，反向注入一定孔隙体积的地层水，对油相渗透率将产生较严重的伤害，伤害率均超过50%，且岩心渗透率越低，伤害越严重。

表2　岩心水锁伤害结果

岩心号	气测渗透率/10^{-3} μm²	初始渗透率/10^{-3} μm²	水锁后渗透率/10^{-3} μm²	渗透率伤害率，%
J6-147-1	44.06	7.69	1.73	77.5
J6-147-2	22.73	2.88	0.39	86.5
K455-1	89.80	17.73	8.34	52.8
K455-2	63.55	12.06	4.09	66.1

2.2　预防水锁实验

将岩心饱和地层水，在相同的条件下用原油驱替，稳定后测油相渗透率，反向注入10倍孔隙体积的新型防水锁处理剂，反应8 h，再将一定量的地层水反向注入岩心，静置2 h后用原油驱替，稳定后测油相渗透率[11]。实验结果（表3）表明，新型防水锁

处理剂在室内岩心流动试验中，能够有效地预防油水乳化堵塞和水锁效应对岩心渗透率的伤害，可使渗透率保留率达85%以上。

表3　岩心防水锁伤害结果

岩心号	气测渗透率/10^{-3} μm^2	初始渗透率/10^{-3} μm^2	预防水锁后渗透率/10^{-3} μm^2	渗透率保留率,%
J6-147-3	48.30	8.23	7.18	87.2
J6-147-4	19.45	2.06	1.76	85.4
K455-3	85.66	16.36	15.18	92.8
K455-4	58.27	10.55	9.47	89.8

3　现场试验

2010年6月至2011年3月在双河油田推广应用新型防水锁处理剂12井次，有效率为100%，取得了显著的效果。典型井例的施工效果统计结果（表4）表明，T12-15井维护作业前产液量为7.1 m^3/d，产油量为1.4 m^3/d，含水率为80.6%，往地层挤注防水锁处理剂后进行维护作业，作业后该井产液量为8.2 m^3/d，产油量为1.5 m^3/d，含水率为81.7%，产油量基本保持不变，收到了明显的预防水锁伤害效果。

表4　双河油田预防水锁伤害施工效果

井号	维护作业前			维护作业后		
	产液量/(m^3·d^{-1})	产油量/(m^3·d^{-1})	含水率,%	产液量/(m^3·d^{-1})	产油量/(m^3·d^{-1})	含水率,%
H4-507	58.2	3.7	93.6	59.3	3.7	93.8
T12-15	7.1	1.4	80.6	8.2	1.5	81.7
T8-148	50.9	2.2	95.7	50.6	2.1	95.8
新7-1271	30	1.0	96.7	55.3	1.4	97.5
T5-3515	28.8	0.9	96.8	44.2	1.0	97.8

4　结论

针对双河油田维护作业后水锁引起油井大幅减产的问题，研制开发了一种新型防水锁处理剂，其与地层水配伍性良好，具有降低界面张力、破乳及防乳化、耐温等性能。

当新型防水锁处理剂注入量为10倍孔隙体积，温度为70 ℃，驱替压力为0.3 MPa，反应时间达到8 h时，岩心渗透率保留率达85%以上，能够有效地预防油水乳化堵塞和水锁效应对岩心渗透率的伤害。

该防水锁处理剂能够有效地预防水锁伤害，现场应用12井次，有效率为100%，具有良好的应用前景。

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编辑　刘北羿

Fu Meilong, Liu Guolin, Wang Rongru et al. Development and application of new waterlock-proof treatment agent. *PGRE*, 2013,20(2):55-57.

Abstracts: In the case of the sharply declining of well production caused by water blockage, which was caused by maintenance operation due to the difference between layers in Shuanghe oilfield. A new type of waterlock-proof treatment agent is developed through laboratory experiments (0.5%SATRO+0.05%alkyl sodium sulfonate+0.03%FX-02). This paper mainly introduces the formulation screening of the waterlock-proof treatment agent and the performance evaluation.The results show that :this product can effectively reduce the interfacial tension between oil and water, causing the interfacial tension to reach ultra low(10^{-3} mN/m); at the same time, the product with a good demulsification performance can make the demulsification rate up to 90% in 3 h; the laboratory core physical model experiment indicates that : when the injection rate of the waterlock-proof treatment agent is 10 PV, temperature of 70 ℃, displacement pressure of 0.3 MPa, reaction time up to 8 h, the remaining ratio of the core permeability reaches up to over 85%, which can effectively prevent emulsification blocking and the formation permeability damage caused by water lock effect. The waterlock-proof treatment agent has been applied in field for 12 wells, whose effective rate is 100%, remarkable results are achieved.

Key words: water lock effect; waterlock-proof treatment agent; interfacial tension; demulsification; Shuanghe oilfield

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Rong Yuanshuai, Li Xinhua, Liu Xueli et al. Discussion about pattern of water flooding development in multi-well fracture-cavity units of carbonate fracture-cavity reservoir in Tahe oilfield. *PGRE*, 2013,20(2): 58-61.

Abstract: During the early stage of the test of water flooding development of multi-well fracture-cavity units in carbonate fracture-cavity reservoir in Tahe oilfield, it emerged some problems such as few efficient well groups, short efficient period and very fast water cut. In accordance with these problems, based on the systematic analysis of the water flooding test early stage and laboratory research, this paper puts forward the pattern of water flooding development of multi-well fracture-cavity units of carbonate fracture-cavity reservoir, which is intended to keep pressure, multi-stage and stereoscopic water flooding. The development of keeping pressure refers to keep the pressure of reservoir to slow down the decline rate caused by the energy decline and to restrain the bottom water coning. The multi-stage development refers to adopt different waterflood pattern, injection-production parameter and matching technology at different stage of water flooding development, it should increase the water injection rate to test the connectivity and construct the injection-production relation before water flooding effect appears, and it should adopt moderate waterflood until the water flood effect become serious, and increase water injection rate for cyclic water flooding and adopt reversing the direction of water injection well and profile control at the later stage. The development of stereoscopic water flooding refers to set up stereoscopic injection-production pattern according to development rule of fracture and cavity, the condition of distribution of residual oil and connectivity, it should adopt the water flooding ways and matching technologies of bidirectional or more directional injection, separated layer water injection, low injection and high production and fracture injecting and cavity production.

Key words: fracture-cavity reservoir; multi-well fracture-cavity units; pattern of water flooding development; keeping pressure; multi-stage; stereoscopic water flooding

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Wei Haifeng, Fan Zheyuan, Yuan Xiangchun. Review on new advances in foreign tight oil development technology and their enlightenment. *PGRE*, 2013,20(2):62-66.

Abstract: This paper summarizes the implication and characteristics of tight oil from different domestic and foreign tight oil definitions and criteria, and statistically analyzes foreign tight oil resources and their distribution. It selects tight oil-gas fields of large development scale or mature technology as the research subject, and analyzes them from different perspectives such as geological properties, development history and status, development status technology, cost of discovery and development, development effect and laws, etc. It concludes the major development technology and policies aiming at different geological conditions, and the variation law of key development indexes including initial production and decline rate. Combined with the tight oil development status and geological characteristics of Sinopec, this paper draws inspirations in terms of geology, technology, basic research, and cost, etc. All these recognitions will be of great reference and guiding significance to the development orientation, technology policy making, recognition of development law, scheme optimization, organization and operation, and management mode of domestic tight oil development technology.

Key words: tight oil reservoir; horizontal well; multi-stage fracturing; advances in technology; development law

Wei Haifeng, Petroleum Exploration and Production Research Institute, SINOPEC, Beijing City, 100083, China

Li Linxiang. Improved recovery method on small oil sandbody in Gudong oilfield. *PGRE*, 2013,20(2):67-70.

Abstract: The small oil sand of Gudong oilfield mostly belongs to meander fluvial sedimentation, which is limited area, poor reservoir